SLEEP TENDENCY AND ABILITY TO SUSTAIN WAKEFULNESS

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INTRODUCTION

During sustained military operations it is often necessary to cope with prolonged periods of wakefulness and irregular rest-activity patterns. In these situations a severe sleep debt can accumulate, leading to increasing levels of sleepiness on the job and, consequently, to dangerous decreases of performance. A number of possible pharmacological and non-pharmacological countermeasures have been studied. Prophylactic naps (short periods of sleep before long periods of work) are probably the best non-pharmacological tool to reduce fatigue and improve performance (e.g., Bonnet, 1991). They have to take place according to some "chronobiological rules": for example, it is well known that sleep propensity shows a biphasic distribution, with an early morning (5.30-7.30 hours) and a mid afternoon (15.30) peak, defined "primary and secondary sleep gates" by Lavie (1986). In addition, naps should be scheduled before the accumulation of a severe sleep debt and placed far from the circadian through of body temperature rhythm, in order to minimize sleep inertia effects (e.g., Dinges, Orne, Orne, 1985).

When operational conditions are characterized by environmental and psychological factors that do not permit to have useful naps, drugs such as benzodiazepines can be used to both induce and maintain sleep (Nicholson, Stone, Pascoe, 1980; Nicholson, Stone, 1986); other drugs (caffeine, amphetamines, modafinil) have been successfully used to sustain wakefulness (e.g., Johnson, Freeman, Spinweber, Gomez, 1991; Pigeau, Angus, 1997).

However, up to now a poor attention has been payed to the individual differences in adaptability to unusual sleep-wake cycles. Individual differences should be carefully taken into account when selecting personnel to be involved in sustained operations and irregular rest-activity schedules. For example, it is well known that evening-type people can more easily adapt to work at night and to sleep during the day than morning-type people (e.g., Breithaupt, 1978). In addition, in the course of prolonged and intensive operations, it is not easy to exactly schedule periods of sleep. In other words people can be required to sleep at unusual hours or "forbidden zones for sleep", and to work during "forbidden zones for wake" (e.g., Walsh, Tepas, Moss, 1981). For these reasons, in applicative contexts can be very relevant to select personnel characterized by both high *sleepability* (the ability to sleep whenever it is permitted) and high *wakeability* (the ability to sustain wakefulness for long periods of time).

A number of tools are available to quantify sleep propensity and/or ability to remain awake during irregular work hours. Objective evaluation of *sleepability* can be obtained by means of the Multiple Sleep Latency Test (-MSLT- Richardson, Carskadon, Flagg, Van den Hoed, Dement, Mitler, 1978). MSLT is based on the idea that drowsiness is close to readiness to fall asleep; in fact subjects are required to lie down in bed and to attempt to fall asleep for several times (4 to 6) during the day, while being polygraphically monitored (EEG, EOG, EMG). The mean duration of sleep latency is considered as measure of sleepiness: the shorter the sleep latency, the higher the sleepiness.

On the other side the *wakeability* is usually assessed with Maintenance of Wakefulness Test (-MWT- Mitler, Gujavarty, Browman, 1982), a variant of the MSLT that requires the subjects to sit in a comfortable, high-backed chair, with their eyes closed, in a darkened room with instruction to "remain awake". The criteria to assess

Paper presented at the RTO HFM Workshop on "Individual Differences in the Adaptability to Irregular Rest-Work Rhythms/Status of the Use of Drugs in Sleep-Wakefulness Management", held in Venice, Italy, 3-4 June 1999, and published in RTO MP-31.

sleepiness are the same used in the MSLT procedure.
MSLT and MWT constitute an assessment of distinct aspects of the sleepiness/alertness dimension, as shown by studies on shift workers and sleep apnea or narcoleptic patients (Sangal, Thomas, Mitler, 1992; Sugerman, Walsh, 1989). In the present study sleepiness and alertness were objectively measured, by means respectively of MSLT and MWT, during the night after a daytime administration 20 mg of Temazepam (TMZ) in soft gelatine capsules or placebo (PLC) to obtain a prophylactic sleep. Furthermore, we here report two "single-case" studies on military pilots complaining of excessive daytime sleepiness.

MATERIALS AND METHODS

Subjects

Eight males (mean age= 33.5 ± 9.4) with no sleep, medical, or psychiatric disorders participated as volunteers in the study. All of the subjects reported a normal rest-activity cycle - with monophasic sleep from 23.00 to 7.00 ± 1 hour - and all of them were drug free.

Polygraphic measures of sleepiness/alertness

During both MSLT and MWT trials, EEG was recorded from four monopolar locations (C3-A2, C4-A1, O1-A2, O2-A1); EOG was recorded from the left and right outer canthus, both referred to FPz. Submental electrodes were employed for recording bipolar EMG. The impedance between electrodes was kept below 10 Kohms. All recordings were in AC. For data collection, a polygraph "VEGA 24" (OTE BIOMEDICA) was used, with a paper speed of 10 mm/sec. Sleep stages were scored according to international standard criteria (Rechtschaffen & Kales, 1968).
Multiple Sleep Latency Test (MSLT). Sleep latencies were recorded in a dark, sound-proof room, with subjects lying in bed attempting to fall asleep, using standard procedure (Carskadon, Dement, Mitler, Roth, Westbrook, Keenan, 1986). Subjects were awoken immediately after two consecutive 30 sec epochs of any stage of sleep, and the score was taken as latency to the first epoch of any stage of sleep. If sleep onset did not occur, a latency of 20 min (the end of the test) was used for data analysis.
Maintenance of Wakefulness Test (MWT). The MWT (Mitler et al., 1982) required the subjects to sit in a comfortable, high-back chair, with their eyes closed, in a darkened room with the instruction "to remain awake". Sleep onset definition and termination criteria were the same used as in the MSLT procedure.

Procedure

The experimental design was based on a double-blind, balanced administration of 20 mg TMZ in soft gelatine capsule or PLC before a daytime sleep. The two conditions (TMZ vs PLC) occured on two non-consecutive days separated by at least 1 week. On each experimental day subjects slept in the laboratory, after the assignment to TMZ or PLC (lights out at 14.30 ± 30 minutes until maximum 22.00).
During the night, starting from 23.00, the subjects underwent four consecutive testing sessions (each one comprising several psychophysiological and paper and pencil tasks assessing attentional performance). The MWT trials were done at the following times: 23.30, 1.30, 3.30, 5.30, while the MSLT trials at 0.30, 2.30, 4.30, 6.30.

Data analysis

Sleep latencies on MWT and MSLT were submitted to a repeated measures ANOVA *Test* (MWT, MSLT) x *Condition* (TMZ, PLC) x *Session* (1,2,3,4) was performed. Trend analysis was used to evaluate time-of-day effects. Duncan test was used for *post hoc* comparisons of the means.

Single-case studies

Two military pilots (P.R. and A.C.), aged respectively 29 and 41 years, complaining of excessive daytime sleepiness, were submitted to four MWT and MSLT sessions during the day, with the following schedule: MWT trials at 11.00, 13.00, 15.00, 17.00; MSLT trials at 11.30, 13.30, 15.30, 17.30.

RESULTS

ANOVA showed a significant effect for *Test* ($F_{1,7}=31.02$; $p=.001$), with shorter mean latencies on MSLT (6.48 min) than on MWT (15.98 min) and for *Session* ($F_{3,21}=12.8$; $p=.0001$), but no effect for *Condition* ($F_{1,7}<1$).

A significant interaction *Test x Session* ($F_{3,21}$=9.0; p<.0005) was present, with trend analysis showing a significant linear trend during the night only for MSLT ($F_{1,7}$= 23.83; p=.002, see Figure 1).
Moreover a significant interaction *Test* x *Condition* ($F_{1,7}$=8.14; p=.02, see Figure 2) was found, with higher latencies on MWT in the TMZ condition (Duncan test: p<.05). Finally, *Test* x *Condition* x *Session* ($F_{3,21}$<1) interaction was not significant. In the table 1 are reported means (± SD) of sleep latencies (in minutes) on MWT and MSLT in the 4 nocturnal sessions of the two conditions.

Table 1. Means (± SD) of sleep latencies (in minutes) on MWT and MSLT in the 4 nocturnal sessions of the PC and TMZ conditions.

Variables	**Nocturnal sessions Post-PLC**				**Nocturnal sessions Post-TMZ**			
	SES 1	SES 2	SES 3	SES 4	SES 1	SES 2	SES 3	SES 4
MWT	16.5	15.87	15.69	12.23	18.36	18.86	14.71	15.31
(Sleep latencies)	(6.48)	(7.65)	(7.46)	(7.96)	(4.02)	(2.10)	(6.49)	(5.93)
MSLT	11.75	7.87	5.75	3.44	8.68	7.44	3.12	3.81
(Sleep latencies)	(4.42)	(7.73)	(7.31)	(4.30)	(5.67)	(4.68)	(1.75)	(3.83)

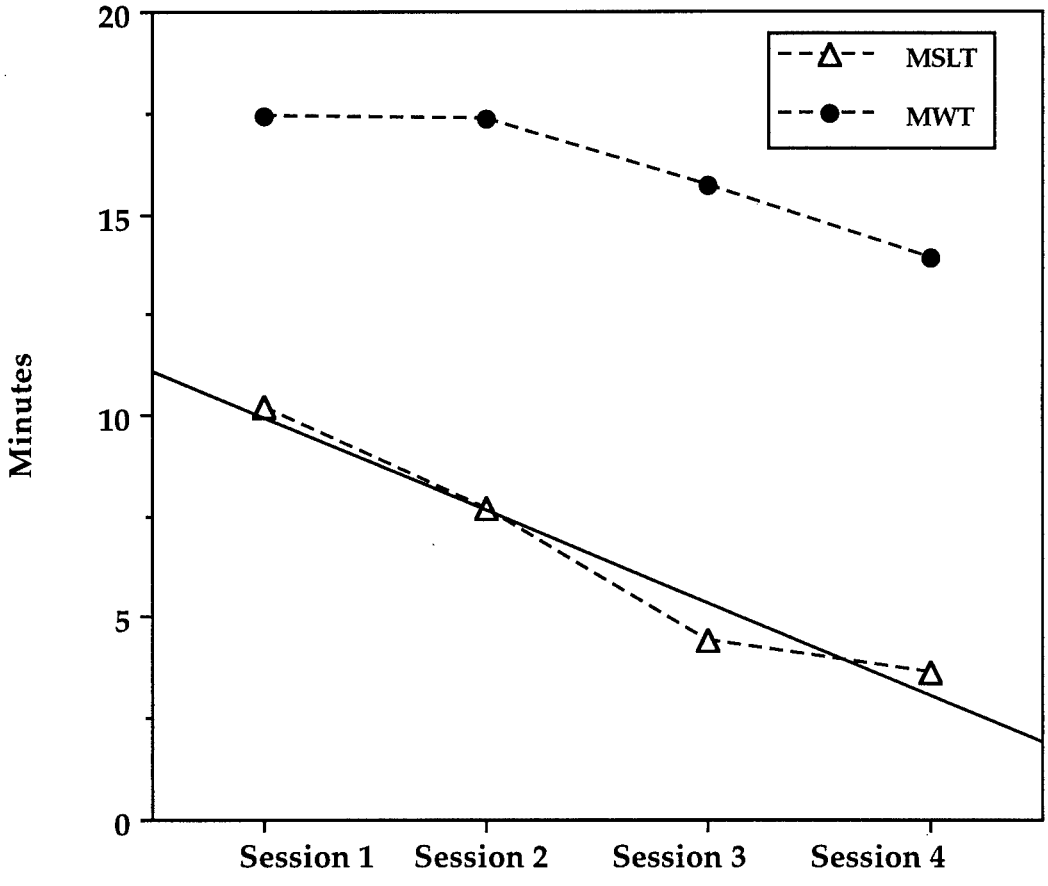

Figure 1. Mean sleep latencies on MWT and MSLT during the four nocturnal sessions. Significant linear trend for time of day effect is indicated by interpolate curve.

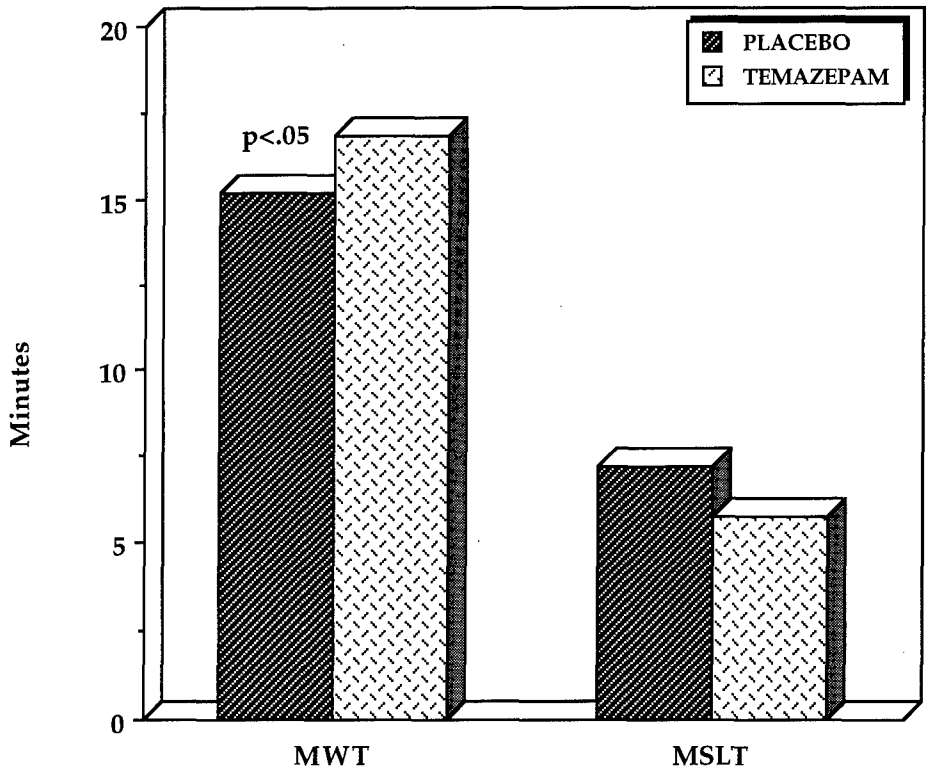

Figure 2. Mean sleep latencies on MWT and MSLT during the night, after diurnal sleep with TMZ or PLC.

With regard to the two single-case studies, the visual inspection of plotted MSLT and MWT latencies (see figures 3 and 4) seems to reveal different patterns of dissociation between *sleepability* and *wakeability*. Subject A.C. showed a high ability to maintain wakefulness during the day never falling asleep at MWT trials, in spite of very short sleep latencies (<5 min) in the first 3 MSLT trials. On the other hand, subject P.R. always showed sleep latencies in the pathological range, except than during the first MWT trial.

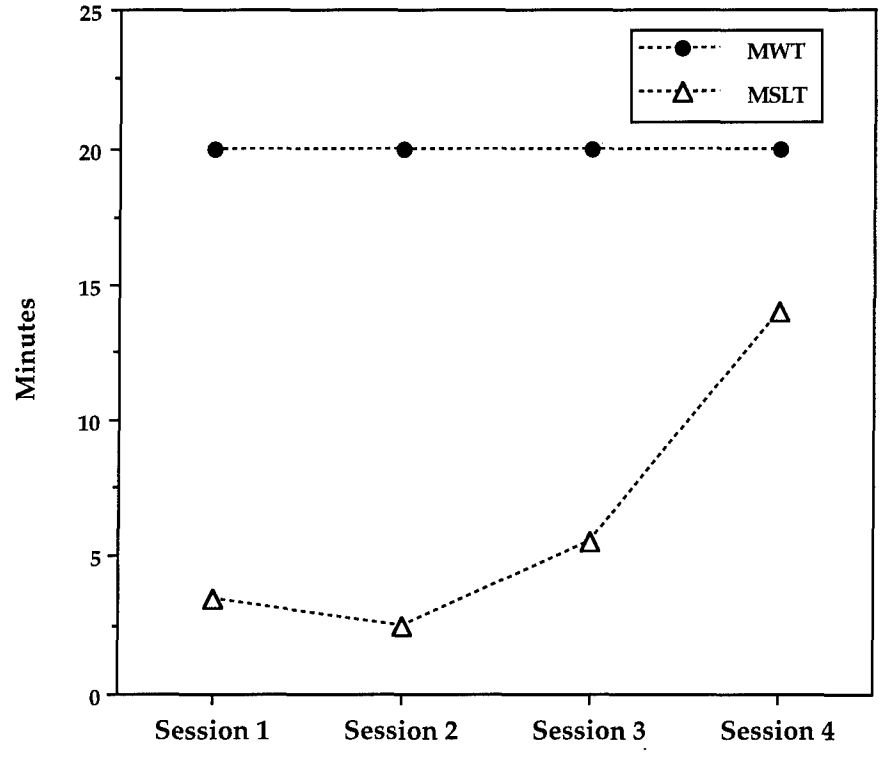

Figure 3. Mean sleep latencies on MWT and MSLT during the day of a military pilot complaining of excessive daytime sleepiness (subject A.C.).

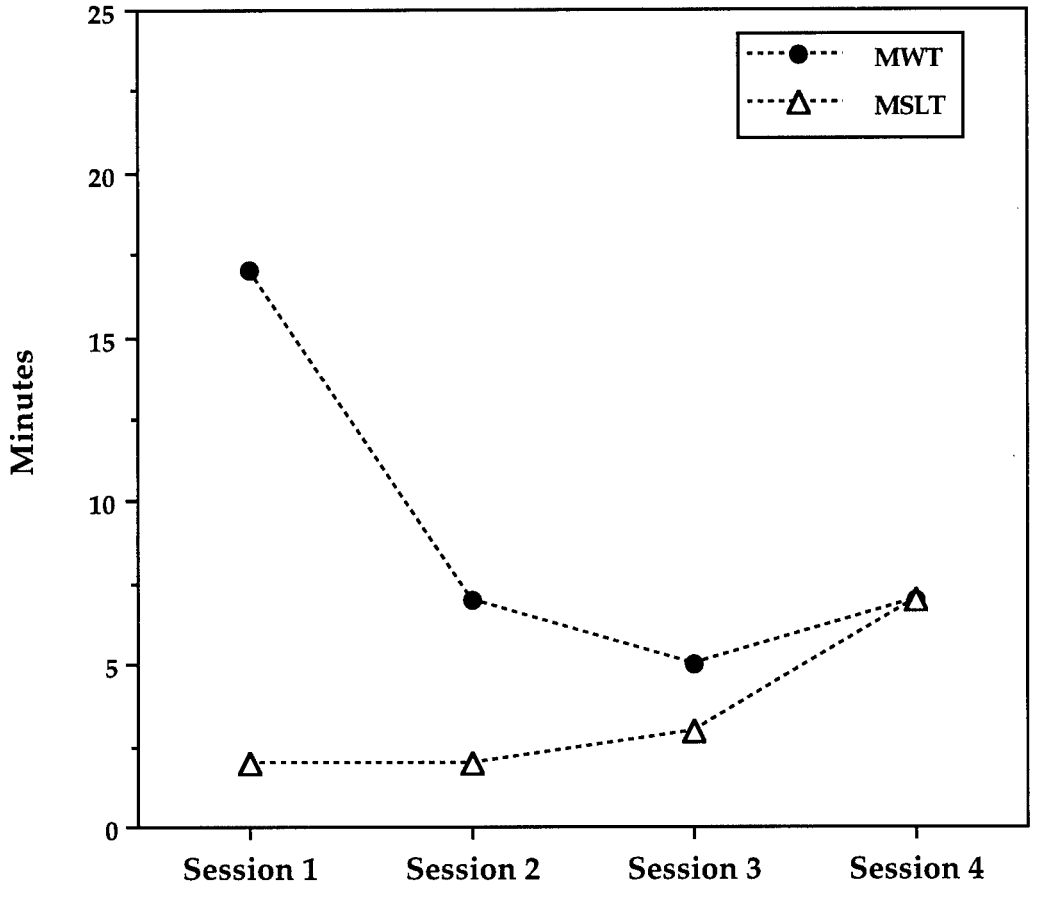

Figure 4. Mean sleep latencies on MWT and MSLT during the day of a military pilot complaining of excessive daytime sleepiness (subject P.R.).

DISCUSSION

Our results confirm that MSLT and MWT constitute assessment of distinct aspects of the sleepiness/alertness dimension (e.g., Porcù, Bellatreccia, Casagrande, Ferrara, Tricarico, 1996). In fact, the ability to stay awake - measured by MWT- was not substantially affected by circadian factors, remaining stable during the night. The circadian trend of sleepiness is better revealed by MSLT, that showed a linear increase of sleep propensity during the night (decreasing sleep latencies on MSLT).

The effect of instructions is confirmed also during the acute night shift following diurnal sleep, being the MSLT sleep latencies significantly shorter than the MWT ones.

In addition, we found higher latencies on MWT in the TMZ condition as compared to the PLC condition; in other words, the assumption of temazepam prior to daytime sleep positively affected the ability to remain awake during the following night. On the contrary, sleep propensity, as reflected by MSLT latencies, was not affected by the lengthening of diurnal sleep after TMZ intake.

Both findings - time-of-day and drug effects - confirm that MWT and MSLT imply different physiological processes, namely *sleepability* and *wakeability*. Such a dissociation between *sleepability* and *wakeability* is also confirmed by the single-case studies here reported. Results regarding subject A.C. clearly indicate that a high ability to maintain wakefulness when requested can coexist with a very high level of daytime sleepiness, as expressed by very short sleep latencies at MSLT (<5 min, in the range of pathology).

Harrison and Horne (1996) recently interpreted the high *sleepability* found in some healthy subjects (short MSLT latencies during the day)

as a simple ability to relax and 'switch off' very efficiently. These subjects seem to be pathologically sleepy, but they do not show any other symptom of excessive daytime sleepiness, are good sleepers, and do not complain of excessive daytime sleepiness. This ability seems to be a relatively stable individual trait in sleep propensity, as Harrison and Horne's subjects showed no improvement to MSLT latencies even under ad libitum sleep conditions.

In conclusion, our results suggest the usefulness to assess *sleepability* and *wakeability* in the selection of personnel eventually required to cope with sustained operations during the night and/or with prolonged irregular rest-activity patterns. .In fact, whenever an abrupt shift of the sleep-wake cycle is required - such as during emergencies, military operations, trans-meridian travels or shift-work - the need to sleep and to properly perform at unusual hours with respect to the underlying circadian rhythm usually leads to cumulative sleep curtailment and decrements of performance (e.g., Tilley, Wilkinson, Warren, Watson, Drud, 1982). In such situations, people that can easily go to sleep in the daytime and sustain wakefulness for long periods of time should be preferably selected.

REFERENCES

Bonnet M. The effect of varying prophylaptic naps on performance, alertness and mood throughout a 52-hour continuous operation. *Sleep* 1991; 14: 307-15.

Breithaupt H. Tolerance to shift of sleep, as related to the individual's circadian phase position. *Ergonomics* 1978; 21: 767-774.

Carskadon M, Dement WC, Mitler M, Roth T, Westbrook P, Keenan S. Guidelines for the multiple sleep latency test (MSLT): A standard measure of sleepiness. *Sleep* 1986;9:519-524.

Dinges D. F., Orne M. T., Orne E. C. Assessing performance upon abrupt awakening from naps during quasi-continuous operations. *Behavior Research Methods, Instruments & Computers* 1985;17(1): 37-45.

Harrison Y, Horne JA. "High sleepability without sleepiness".The ability to fall asleep rapidly without other signs of sleepiness. *Neurophysiologie Clinique* 1996;26:15-20.

Johnson L, Freeman C, Spinweber C, Gomez S. Subjective and objective measures of sleepiness: effect of benzodiazepine and caffeine on their relationship. *Psychophysiology* 1991; 28: 65-71.

Lavie P. Ultrashort sleep-waking schedule. III. Gates and <forbidden zones> for sleep. *Electroencephalography and Clinical Neurophysiology* 1986; 63: 414-425.

Mitler M, Gujavarty K, Browman C. Maintenance of wakefulness test: a polysomnographic technique for evaluating treatment efficacy in patients with excessive somnolence. *Electroencephalography and Clinical Neurophysiology* 1982;53:658-661.

Nicholson A, Stone B, Pascoe P. Studies on sleep and performance with a triazolo-1,4, thienodiazepine (brotizolam). *British Journal of Clinical Pharmacology* 1980; 10: 75-81.

Nicholson A, Stone B. Hypnotics and transient insomnia. *Acta Psychiatrica Scandinavica* 1986; 74 Suppl. 332: 55-59.

Pigeau R, Angus R. The efficacy of naps vs modafinil and amphetamine to ameliorate the effects of sustained operations. *NATO DRG Workshop "Sleep Managment in the military"*, Pratica di Mare, 21-22 April 1997, Abstract Book, p. 14.

Porcù S., Bellatreccia A., Casagrande M., Ferrara M., Tricarico A. (1996) Sleepiness during an acute night shift: neurophysiological correlates and effects on performance. *AGARD - CP-579* 1996: 33-1/33-7.

Rechtschaffen A, Kales A, eds. *A manual of standardized terminology, techniques and scoring system for sleep stages of human subjects*. Los Angeles: Brain Information Service/Brain Research Institute, University of California, 1968.

Richardson G, Carskadon M, Flagg W, Van den Hoed J, Dement W, Mitler M. Excessive daytime sleepiness in man: multiple sleep latency measurements in narcoleptics vs. control subjects. *Electroencephalography and Clinical Neurophysiology* 1978; 45: 621-27.

Sangal R, Thomas L, Mitler M. Disorders of excessive sleepiness. Treatment improves ability to stay awake but does not reduce sleepiness. *Chest* 1992;102:699-703.

Sugerman JL, Walsh JK. Physiological sleep tendency and ability to maintain alertness at night. *Sleep* 1989;12(2):106-112.

Tilley A, Wilkinson R, Warren P, Watson W, Drud M. The sleep and performance of shift workers. *Human Factors* 1982;24:624-641.

Walsh J, Tepas D, Moss P. The EEG sleep of night and rotating shift workers. In: Johnson LC, Tepas DI, Colquhoun WP, Colligan M, eds. *Biological rhythms, sleep and shift work* . New York: Spectrum, 1981: 371-381